

DESCRIPTION**CLAD MATERIAL, METHOD FOR MANUFACTURING SAID CLAD MATERIAL, AND
APPARATUS FOR MANUFACTURING SAID CLAD MATERIAL**

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Priority is claimed to Japanese Patent Application No. 2004-35186 filed on February 12, 2004, and U.S. Provisional Application No. 60/545,530 filed on February 19, 2004, the disclosure of which are incorporated by reference in their entireties.

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Cross Reference to Related Applications

This application is an application filed under 35 U.S.C. §111(a) claiming the benefit pursuant to 35 U.S.C. §119(e)(1) of the filing date of U.S. Provisional Application No. 60/545,530 filed on February 19, 2004, pursuant to 35 U.S.C. §111(b).

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Technical Field

The present invention relates to a clad material with skin materials laminated on both sides of a core material for giving, for example, brazing performance and corrosion resistance, especially, a clad material excellent in high-temperature strength, a method for manufacturing such clad material, and an apparatus for manufacturing such clad material.

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Background Art

The following description sets forth the inventor's knowledge

of related art and problems therein and should not be construed as an admission of knowledge in the prior art.

In recent years, in accordance with reduction in size and weight and improvement in performance of heat exchanges, the materials thereof are required to be thin in thickness and high in strength. Furthermore, for the purpose of decreasing environmental burden, a request of alternatives for chlorofluorocarbon has increased, and therefore a request of heat exchangers using CO₂ as refrigerant has increased. Examples of such heat exchangers meeting the above demands include heat exchangers represented by radiators and heater cores, which use water as a principal component of refrigerant, heat exchangers represented by condensers and evaporators, which use freon gas as refrigerant, and heat exchangers represented by gas coolers (evaporators), which use CO₂ as refrigerant.

As a component for use in these heat exchangers, a clad material consisting of an aluminum alloy core and an aluminum alloy skin material which gives brazing performance and corrosion prevention performance to the surface of the core and having sufficient strength even after brazing has been used. In a generally employed method for manufacturing such clad material, a pre-heated ingot is hot-rolled and then the surface thereof is scraped to obtain a core material having a thickness of 250 mm to 400 mm. The core material and a skin material having a thickness of 10 to 100 mm are placed one on another and then temporarily fixed with each other. Thereafter, the temporarily fixed members are subjected to hot-rolling, cold-rolling and, if necessary, intermediate annealing.

As a material of the aforementioned aluminum alloy core material, there is an Al-Mn series alloy plate improved in high temperature strength by manufacturing under predetermined heat-treating conditions and rolling conditions. However, although these Al-Mn series alloy plates are excellent in characteristics as elementary substance, they can give simultaneously neither brazing performance nor corrosion prevention performance (Japanese Unexamined Laid-open Patent Publication No. 2000-104149 and Japanese Unexamined Laid-open Patent Publication No. 2002-241910).

Moreover, as for the method for manufacturing a clad material, in place of the aforementioned hot-rolling method, various methods utilizing continuous casting of core materials have been proposed (Japanese Unexamined Laid-open Patent Publication No. H11-226699, Japanese Laid-open Patent Publication No. H8-509265 and Japanese Laid-open Patent Publication No. 2002-248599).

Japanese Unexamined Laid-open Patent Publication No. H11-226699 discloses a method for continuously manufacturing a clad material in which a skin material is pressure-bonded to a core material which is being sent out from a cast rolling mill with pressure-bonding rolls disposed at the vicinity of the outlet side of the rolling mill. Also disclosed in Figs. 11e and 11f of Japanese Laid-open Patent Publication No. H8-509265 is a method for continuously casting a core material and cladding of the core material and a skin material with pressure-bonding rolls disposed at the outlet side of the cooling rollers of the cast rolling mill.

On the other hand, disclosed in Figs. 11a, 11b and 11c of Japanese

Laid-open Patent Publication No. H8-509265 is a method for manufacturing a clad material in which casting of a core material and pressure-bonding of the core material and the skin material are simultaneously performed by supplying the skin material at the inlet side of molten alloy with cooling rollers of the cast rolling apparatus. Also disclosed in Japanese Laid-open Patent Publication No. 2002-248599 is a method for supplying a skin material at the inlet side of cooling rollers for casting a core material when manufacturing a clad material in which the width of the skin material is wider than that of the core material and the skin material is embedded in the core material.

However, there were the following problems in the manufacturing method of the aforementioned clad material.

That is, according to the method in which pressure-bonding of the skin material to the core material is performed after the casting of the core material, since it is necessary to arrange a cast rolling mill and a pressure-bonding roll, the equipment becomes complicated in structure, and the production rate is restricted by the continuous casting rate of the core material. Furthermore, deterioration of adhesiveness of the skin material due to a segregation layer containing oxide formed on the surface at the time of continuous cast rolling and deterioration of corrosion characteristics at the interface cannot be suppressed.

On the other hand, according to the method for simultaneously performing the casting of the core material and the pressure-bonding of the skin material to the core material, since the position where

the skin material comes into contact with the molten metal (core material) at the inlet side of the cooling rollers becomes unstable, a part of the skin material may melt, or even may be broken.

Furthermore, according to Japanese Laid-open Patent Publication No. 2002-248599, since the width of the core material is larger than that of the skin material and therefore the molten metal partially comes into contact with the cooling rollers, the roll surface property changes, resulting in difficulty in controlling the roll surface property for a long time.

The description herein of advantages and disadvantages of various features, embodiments, methods, and apparatus disclosed in other publications is in no way intended to limit the present invention. Indeed, certain features of the invention may be capable of overcoming certain disadvantages, while still retaining some or all of the features, embodiments, methods, and apparatus disclosed therein.

Other objects and advantages of the present invention will be apparent from the following preferred embodiments.

Disclosure of Invention

The preferred embodiments of the present invention have been developed in view of the above-mentioned and/or other problems in the related art. The preferred embodiments of the present invention can significantly improve upon existing methods and/or apparatuses.

The present invention was made in view of the aforementioned

problems, and aims to provide a method for manufacturing a clad material capable of keeping the surface property of cooling rollers constant while keeping high cooling rate of a core material, restraining deterioration of adhesiveness of a skin layer due to
5 contamination of non-metallic inclusion such as an oxide film formed at the interface of the skin material and the core material, and restraining occurrence of thickness variation of the skin material after the cladding and/or breakage of the skin material during the manufacturing process. Furthermore, the present invention also
10 aims to provide a clad material manufactured by the aforementioned method and an apparatus for manufacturing a clad material for executing the aforementioned method.

The method for manufacturing a clad material according to the present invention has the following structures as recited in Items
15 (1) to (11).

(1) A method for manufacturing a clad material, comprising the steps of:

continuously supplying molten metal into a gap between a pair of cooling rollers to cast a core material; and

20 cladding skin materials on both surfaces of the core material with hot rolling by continuously supplying the skin materials on peripheral surfaces of the cooling rollers so that the skin materials prevent direct contact between the cooling rollers and the molten metal,

25 wherein the skin materials are supplied so as to come into contact with the peripheral surfaces of the cooling rollers, and

wherein a contact distance (L1) from a contact starting point (P1) where the skin material begins to come into contact with the cooling roller to a meeting point (P2) where the skin material begins to come into contact with the molten metal is set to 100 times or
5 more of a thickness (t1) of the skin material.

(2) The method for manufacturing a clad material as recited in the aforementioned Item 1, wherein the core material and the skin material are made of aluminum or its alloy.

(3) The method for manufacturing a clad material as recited
10 in the aforementioned Item 1, wherein the thickness (t1) of the skin material is 20 to 400 μm .

(4) The method for manufacturing a clad material as recited in the aforementioned Item 2, wherein at least one of the skin materials is made of Al-Si series alloy.

15 (5) The method for manufacturing a clad material as recited in the aforementioned Item 4, wherein the Al-Si series alloy consists essentially of

Si: 5 to 15 mass%,

Fe: 0.05 to 0.6 mass%,

20 Cu: 0.01 to 0.6 mass%,

Mn: 0.01 to 0.8 mass%,

Mg: 0.01 to 0.2 mass%,

Ti: 0.01 to 0.2 mass%, and

the balance being Al and inevitable impurities.

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(6) The method for manufacturing a clad material as recited

in the aforementioned Item 2, wherein at least one of the skin materials is made of Al-Zn series alloy.

(7) The method for manufacturing a clad material as recited in the aforementioned Item 6, wherein the Al-Zn series alloy consists
5 essentially of

Si: 0.05 to 0.6 mass%,

Fe: 0.05 to 0.6 mass%,

Cu: 0.01 to 0.6 mass%,

Mn: 0.01 to 0.8 mass%,

10 Mg: 0.01 to 0.2 mass%,

Ti: 0.01 to 0.2 mass%,

Zn: 0.35 to 8.5 mass%, and

the balance being Al and inevitable impurities.

(8) The method for manufacturing a clad material as recited
15 in the aforementioned Item 1, wherein a thickness (t₂) of the skin material after hot roll cladding is 0.5 to 8 mm.

(9) The method for manufacturing a clad material as recited in the aforementioned Item 2, wherein the molten metal to become the core material consists essentially of

20 Si: 0.05 to 1.5 mass%,

Fe: 0.05 to 2 mass%,

Cu: 0.05 to 0.8 mass%,

Mn: 0.15 to 2.8 mass%,

at least one of elements selected from the group consisting
25 of Cr: 0.03 to 0.7 mass%, Mg: 0.01 to 0.2 mass%, Ti: 0.01 to 0.3 mass%, and Zn: 0.01 to 1.5 mass%, and

the balance being Al and inevitable impurities.

(10) The method for manufacturing a clad material as recited in the aforementioned Item 9, wherein the molten metal further includes at least one of elements selected from the group consisting of Zr: 0.15 to 1.5 mass%, V: 0.03 to 1.5 mass%, and Sc: 0.02 to 0.5 mass%.

(11) The method for manufacturing a clad material as recited in any one of the aforementioned Items 1 to 10, wherein cold rolling is performed after the hot roll cladding.

10 A clad material according to the present invention has the following structures as recited in Items (12) to (15).

(12) A clad material in which skin materials are clad on both surfaces of a core material, wherein the clad material is manufactured by the steps of continuously supplying molten metal into a gap between a pair of cooling rollers to cast a core material, and cladding skin materials on both surfaces of the core material with hot rolling by continuously supplying the skin materials on peripheral surfaces of the cooling rollers so that the skin materials prevent direct contact between the cooling rollers and the molten metal, wherein the skin materials are supplied so as to come into contact with the peripheral surfaces of the cooling rollers, and wherein a contact distance (L1) from a contact starting point (P1) where the skin material begins to come into contact with the cooling roller to a meeting point (P2) where the skin material begins to come into contact with the molten metal is set to 100 times or more of a thickness (t1) of the skin material.

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(13) The clad material as recited in the aforementioned Item 12, wherein the clad material is cold rolled after the hot roll cladding.

(14) The clad material as recited in the aforementioned Item 5 12, wherein an average dendrite secondary arm spacing of the core material formed by the heat roll cladding is 0.1 to 10 μm .

(15) The clad material as recited in any one of the aforementioned Items 12 to 14, wherein the clad material is heat exchanger component material.

10 The apparatus for manufacturing a clad material according to the present invention has the following structures as recited in Item (16).

(16) An apparatus for manufacturing a clad material, comprising:

15 a pair of cooling rollers for continuously casting molten metal passing through a gap formed between the cooling rollers;

a molten metal supplying portion for supplying the molten metal to become a core material into the gap; and

a skin material supplying portion for supplying a skin material 20 on a peripheral surface of the cooling roller and making the skin material come into contact with the peripheral surface of the cooling roller before the skin material joins the molten metal,

wherein the cooling rolls are rotated while continuously supplying the molten metal and the skin material to the cooling 25 rolls to thereby continuously clad the skin materials to both surfaces of the core material.

Effects of the invention

According to the manufacturing method of the clad material of the invention as recited in the aforementioned Item (1), since the skin materials are joined to the molten metal in a state in which the skin material is cooled, the molten metal is solidified quickly by being cooled by the cooling rollers. Therefore, a core material having high hardness can be cast and the skin materials can be pressure-bonded to both surfaces of the core material. Since the skin material is cooled in advance, melting and/or fusing of the skin material due to the heat of the molten metal M can be prevented, and a clad material can be manufactured efficiently without reducing the cooling rate of the core material. Moreover, since the aforementioned skin materials are pressure-bonded during the solidification process of the core material, high adhesion can be attained. Furthermore, since the cooling rollers and the molten metal are intercepted by the skin material, the alteration and deterioration of the roll surface property due to adhesion of the molten metal can be prevented.

According to the invention as recited in the aforementioned Item (2), the aforementioned clad material which consists of aluminum or its alloy can be manufactured.

According to the invention as recited in the aforementioned Item (3), tension control of the skin material can be performed smoothly, and sufficient cooling rate of the core material can be secured.

According to the invention as recited in the aforementioned Item (4), an aluminum brazing clad material with brazing material clad on the surface can be manufactured.

According to the invention as recited in the aforementioned
5 Item (5), the aluminum brazing clad material excellent in especially brazing performance can be manufactured.

According to the invention as recited in the aforementioned Item (6), the aluminum brazing clad material excellent in corrosion resistance in which a sacrificial corrosion layer is formed on the
10 surface can be manufactured.

According to the invention as recited in the aforementioned Item (7), the aluminum brazing clad material excellent in especially corrosion resistance can be manufactured.

According to the invention as recited in the aforementioned
15 Item (8), molten metal can be supplied stably and it is possible to secure the heat releasing capacity from the cooling rollers.

According to the invention as recited in the aforementioned Item (9), an aluminum brazing clad material excellent in strength even at high temperature and excellent in corrosion resistance can
20 be manufactured.

According to the invention as recited in the aforementioned Item (10), the aluminum material excellent in especially high temperature strength can be manufactured.

According to the invention as recited in the aforementioned
25 Item (11), the clad material having a prescribed thickness can be manufactured.

The clad material according to the invention as recited in the aforementioned Item (12) is excellent in adhesiveness property between the skin materials and the core material, or is a useful clad material to which various characteristics, such as brazing performance, corrosion resistance and strength, are further added. Furthermore, the clad material is excellent in workability.

According to the invention as recited in the aforementioned Item (13), a clad material having a prescribed thickness can be obtained.

According to the invention as recited in the aforementioned Item (14), a clad material especially excellent in strength can be obtained.

According to the invention as recited in the aforementioned Item (15), the clad material is useful as a heat exchanger structure component material.

According to the manufacturing apparatus of a clad material of the invention as recited in the aforementioned Item (16), the manufacturing method of the present invention is executed and a clad material can be manufactured efficiently.

The above and/or other aspects, features and/or advantages of various embodiments will be further appreciated in view of the following description in conjunction with the accompanying figures. Various embodiments can include and/or exclude different aspects, features and/or advantages where applicable. In addition, various embodiments can combine one or more aspect or feature of other embodiments where applicable. The descriptions of aspects,

features and/or advantages of particular embodiments should not be construed as limiting other embodiments or the claims.

Brief Description of Drawings

5 Fig. 1 is a schematic view showing an apparatus structure for executing a method for manufacturing a clad material according to the present invention.

 Fig. 2 is a perspective view showing a brazed article used in a brazing test.

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Best Mode for Carrying Out the Invention

 In the following paragraphs, some preferred embodiments of the invention will be described by way of example and not limitation. It should be understood based on this disclosure that various other
15 modifications can be made by those in the art based on these illustrated embodiments.

 A method for manufacturing a clad material according to a preferable embodiment of the present invention will be described in detail with reference to the clad material manufacturing apparatus
20 1 shown in Fig. 1.

 In Fig. 1, the reference numeral 2a and 2b denote a pair of cooling rollers disposed at a certain distance, the reference numeral 3 denotes a nozzle which injects molten metal M supplied from a molten-metal preparation portion, such as a melting furnace and
25 a tundish (not shown), into the gap between the aforementioned cooling rollers 2a and 2b. The aforementioned nozzle 3 sets the meeting

point P2 of the molten metal M and the skin material 10a and 10b by the opening width and the set position. The aforementioned nozzle 3 demonstrates effective roles for preventing melt breakage of the skin material and holding the clad ratio (skin material / core material / skin material) constant. The reference numeral 4a (4b) denotes a holding roll for holding down the skin material 10a (10b) continuously supplied by unwinding the skin material coil (not shown) toward the cooling roller 2a (2b). By adjusting the holding position of the holding roll 4a (4b), the contact starting point P1 where the skin material 10a (10b) begins to come into contact with the cooling roller 2a (2b) is set. The reference numeral 11 denotes a plate-shaped core material made of cast molten metal M, and the reference numeral 12 denotes a three-layered clad material in which the skin materials 10a and 10b are clad on both surfaces of the aforementioned core material 11.

In the manufacturing method of the clad material according to the present invention, when supplying the skin material 10a (10b) to the cooling roller 2a (2b), the skin material 10a (10b) is cooled by coming into contact with the peripheral surface of the cooling roller 2a (2b) before joining the molten metal M, and therefore the skin material 10a (10b) joins the molten metal M in a cooled state. For this reason, the molten metal M supplied to the gap between the cooling rollers 2a and 2b is quickly solidified by being cooled by the cooling roller 2a (2b) even via the skin material 10a (10b), and the skin material 10a (10b) is pressure-bonded and clad on both surfaces of the core material 11. Furthermore, since the skin

material 10a (10b) is to be pressure-bonded to the core material 11 during the solidification process of the core material 11, contamination, such as an oxide film, to the interface between the skin material 10a (10b) and the core material 11 can be prevented, resulting in excellent adhesiveness of the skin material 10a (10b) to the core material 11. Since the aforementioned skin material 10a (10b) is cooled beforehand, the melting and fusing of the skin material due to the heat of the molten metal M can be prevented, and therefore the clad material 12 can be manufactured efficiently without reducing the cooling rate of the core material 11. Moreover, since the molten metal M and the cooling roller 2a (2b) are intercepted by the aforementioned skin material 10a (10b), alteration and/or deterioration of the roll surface property due to the adhesion of the molten metal M can be prevented.

The contact distance L1 of the skin material 10a (10b) along which the aforementioned skin material 10a(10b) is pre-cooled by the cooling roller (2a) 2b, namely, the distance from the contact starting point P1 where the skin material 10a (10b) comes into contact with the cooling roller 2a (2b) to the meeting point P2 where the skin material 10a (10b) comes into contact with the molten metal M, it is necessary to set such that the contact distance L1 is set to a length of 100 times or more of the thickness t1 of the skin material 10a (10b) in order to fully cool the skin material 10a (10b) and to acquire the aforementioned effects. More preferably, the contact distance L1 is set to a length of 200 times to 100,000 times of the thickness t1 of the skin material 10a (10b).

It is possible to attain the aforementioned manufacturing conditions by setting the contact distance $L1$ so that the ratio of the contact distance to the thickness of the skin material ($L1/t1$) falls within the aforementioned range. For example, by changing
5 the diameter of the cooling rollers 2a (2b) and the contact starting point P1 where the skin material 10a (10b) begins to come into contact with the cooling roller 2a (2b) so as to meet the aforementioned range, the range of the roller with which the skin material 10a (10b) is in contact, namely, the contact distance $L1$, can be adjusted.
10 In cases where the contact distance $L1$ is represented by a center angle as seen from the center of the cooling roller 2a (2b), it is preferable to adjust the range of the center angle so as to fall within the range of from 10 to 270°. If it falls within this range, it becomes easy to arrange the devices, and the skin material can
15 be stably wound on the cooling roller 2a (2b). It is more preferable to adjust the range so as to fall within the range of from 150 to 180°.

It is preferable that the thickness $t1$ of the aforementioned skin material 10a (10b) is 20 to 400 μm . If it is less than 20 μm ,
20 it becomes difficult to control the tension of the unwinding roll, which in turn makes it difficult to perform continuation operation due to the possible breakage of the skin material. On the other hand, if it exceeds 400 μm , the heat capacity of the skin material 10a (10b) increases. Therefore, the heat releasing capacity of the
25 cooling roller 2a (2b) becomes insufficient, resulting in insufficient cooling rate. The preferable thickness $t1$ of the skin

material 10a (10b) is 20 to 200 μm . The thickness of the skin material 10a (10b) is not required to be the same in both sides, and the skin materials different in thickness can be employed. Accordingly, the contact distances L1 of both skin materials can also be different
5 with each other.

The thickness t2 of the core material 11 after the hot cladding is preferably 0.5 to 8 mm. Since the present invention employs continuous casting using a pair of cooling rollers 2a and 2b, if the plate thickness t2 after the cladding is less than 0.5 mm, the roll gap is too narrow to stably supply molten metal M. On the other
10 hand, if the thickness exceeds 8 mm, the heat releasing capacity through the cooling roller 2a (2b) becomes insufficient, which makes it difficult to secure sufficient cooling rate of the core material. The preferable thickness t2 of the core material 11 is 0.8 to 6
15 mm.

As will be understood from the above, it is possible to cast a core material 11 excellent in high-temperature strength and efficiently manufacture a three-layered structural clad material 12 with skin materials 10a and 10b clad on both surfaces of the
20 core material 11.

As for the aforementioned cooling rollers, the number of revolutions of the cooling rollers, and the materials of the cooling rollers, it is possible to employ conventionally known ones, provided that cooling conditions of materials are sufficiently met under
25 the aforementioned L1/t1 condition. For example, the diameter of the roller is preferably 100 to 1,000 mm since such a cooling roll

can be easily manufactured or obtained and therefore the entire apparatus can be constituted at lower cost. Furthermore, the number of revolutions of the cooling roller is preferably 1 to 200 m/min., more preferably 5 to 150 m/min. in circumferential velocity. As the materials of the cooling rollers, aluminum or its alloy, copper or its alloy, and iron or its alloy can be exemplified.

In the aforementioned clad material 12, the materials of the core material 11 and the skin material 10a and 10b are metal, and aluminum and its alloy can be exemplified as such metal. The clad material made of aluminum or its alloy can be used as component material which constitutes, for example, fluid passages, tubes, heat releasing fins of heat exchangers.

As the core material and the skin material made of aluminum or its alloy, the following material can be recommended.

As for the skin material, it is preferable to use Al-Si series alloy which functions as brazing material and Al-Zn series alloy which gives corrosion resistance.

As the aforementioned Al-Si series alloy, it is preferable to use alloy consisting of Si: 5 to 15 mass%, Fe: 0.05 to 0.6 mass%, Cu: 0.01 to 0.6 mass%, Mn: 0.01 to 0.8 mass%, Mg: 0.01 to 0.2 mass%, Ti: 0.01 to 0.2 mass%, and the balance being Al and inevitable impurities.

The reasons of adding each element in the aforementioned Al-Si series alloy are as follows.

Si is an element which makes the alloy function as brazing material by lowering the melting point of the alloy. The preferable

Si content is 6.5 to 11 mass%. Fe is an element to be added to improve the wettability of brazing material, and if the content is less than 0.05 mass%, the effects will become poor. To the contrary, if it exceeds 0.6 mass%, large and rough intermetallic compound will be generated, which gives adverse effects on corrosion resistance. The preferable Fe content is 0.1 to 0.5 mass%. Cu is an element to be added to control the electric potential of the skin material (Al-Si series alloy). For example, in cases where the clad material 12 is used as a brazing tube of a heat exchanger, the electric potential of the brazing material becomes unnecessarily less noble with respect to the tube. Therefore, Cu is added to restrain an occurrence of preferential corrosion of fillets. The preferable Cu content is 0.02 to 0.5 mass%. Mn is an element to be added to control the electric potential of the brazing material like Cu. If the content exceeds 0.8 mass%, the flowing characteristics of the brazing material may be inhibited. The preferable Mn content is 0.02 to 0.6 mass%. Mg is an element to be added to improve the strength. If it is less than 0.01 mass%, the effects become poor. To the contrary, it exceeds 0.2 mass%, the brazing performance will be inhibited remarkably. The preferable Mg content is 0.01 to 0.1 mass%. Ti is an element to be added to control the electric potential of the brazing material. The preferable Ti content is 0.01 to 0.1 mass%.

As the aforementioned Al-Zn series alloy, it is preferable to use an alloy consisting of Si: 0.05 to 0.6 mass%, Fe: 0.05 to 0.6 mass%, Cu: 0.01 to 0.6 mass%, Mn: 0.01 to 0.8 mass%, Mg: 0.01

to 0.2 mass%, Ti: 0.01 to 0.2 mass%, Zn: 0.35 to 8.5 mass%, and the balance being Al and inevitable impurities.

The reasons of adding each element in the aforementioned Al-Zn series alloy are as follows.

5 Zn is an element which is dissolved in Al to make the skin material function as a sacrificial corrosion layer of the core material. The preferable Zn content is 0.35 to 6 mass%. Si is an element to be added to improve the strength, and the preferable Si content is 0.1 to 0.5 mass%. Although Fe is an element to be added to improve the strength, if it exceeds 0.6 mass%, large and rough intermetallic compounds will be generated, which may cause a deterioration of corrosion resistance. The preferable Fe content is 0.1 to 0.5 mass%. Cu is an element to be added to control the electric potential of the skin material. The preferable Cu content is 0.02 to 0.3 mass%. Mn is an element to be added to control the electric potential of the skin material. The preferable Mn content is 0.02 to 0.6 mass%. Mg is an element to be added to improve the strength. If it is less than 0.01 mass%, the effects cannot be obtained. To the contrary, if it exceeds 0.2 mass%, the brazing performance may be remarkably inhibited. The preferable Mg content is 0.01 to 0.1 mass%. Ti is an element to be added to control the electric potential of the skin material. The preferable Ti content is 0.01 to 0.1 mass%.

The skin material having the aforementioned composition can be clad on at least one surface of the core material. A skin material to be clad on the other surface of the core material can be a skin

material having a composition the same as or different from that of the aforementioned skin material.

On the other hand, as the core material 11, i.e., the molten metal M, it is preferable to use alloy consisting of at least one of elements selected from the group consisting of Si: 0.05 to 1.5 mass%, Fe: 0.05 to 2 mass %, Cu: 0.05 to 0.8 mass %, Mn: 0.15 to 2.8 mass%, at least one element selected from the group consisting of Cr: 0.03 to 0.7 mass%, Mg: 0.01 to 0.2 mass%, Ti: 0.01 to 0.3 mass% and Zn: 0.01 to 1.5 mass%, and the balance being Al and inevitable impurities. Furthermore, in the composition of the aforementioned molten metal M, it is preferable to further contain at least one element selected from the group consisting of Zr: 0.15 to 1.5 mass%, V: 0.03 to 1.5 mass%, and Sc: 0.02 to 0.5 mass%.

The reasons of adding each element in the composition of the aforementioned core material are as follows.

Si is an element to be added to improve the strength, and the preferable Si content is 0.5 to 1.2 mass%. Fe is an element to be added to improve the strength. If it exceeds 2 mass%, intermetallic compounds, such as an Al-Fe-Mn-Si series, will be generated, which may inhibit corrosion resistance. The preferable Fe content is 0.1 to 0.5 mass%. Cu is an element to be added to control the electric potential, cause the electric potential to be noble than the electric potential of the skin material by adding Cu, and perform corrosion prevention of the core material. The preferable Cu content is 0.05 to 0.6 mass%. Mn is an element to be added to improve the strength, especially to improve the strength at high temperature. The

preferable Mn content is 0.5 to 2.5 mass%. Cr is an element to be added to improve the high temperature strength, and the preferable Cr content is 0.05 to 0.3 mass%. Mg is an element which is dissolved in Al to improve the high temperature strength, and the preferable Mg content is 0.05 to 0.2 mass%. Ti makes electric potential noble, and is an element to be added to change the corrosion from pitting corrosion to layer corrosion, and the preferable Ti content is 0.05 to 0.25 mass%. Zn is an element added to control the electric potential, and the preferable Zn content is 0.1 to 1 mass%.

Zr, V, and Sc which are added arbitrarily are elements to be added for the purpose of raising the recrystallizing temperature and raising the high temperature strength. The preferable Zr content is 0.15 to 0.8 mass%. The preferable V content is 0.1 to 1 mass%. The preferable Sc content is 0.04 to 0.5 mass%. It is sufficient that at least one of Zr, V, and Sc is included. However, two or all of three elements can be included.

The clad material manufactured from the aluminum or aluminum alloy mentioned above can be formed into a predetermined thickness by further subjecting it to cold rolling if necessary. Moreover, heat treating after the cladding or cold rolling can also be performed arbitrarily.

The clad material manufactured by the manufacturing method of the present invention is excellent in high-temperature strength due to the rapid solidification of the core material. Furthermore, since the breakage thereof at the time of machining seldom occurs, the clad material can be a clad material excellent in workability.

Especially in the crystalline structure of the core material, the clad material whose average dendrite secondary arm spacing (DAS) is 0.1 to 10 μm has high-temperature strength. The more preferable average dendrite secondary arm spacing is 0.1 to 8 μm . Furthermore, 5 the skin material to which brazing performance and corrosion prevention performance was given by the skin material having the prescribed components can be preferably used as a brazing material of heat exchanger components, such as a fluid passage, a tube and a heat releasing fin, to be used in high temperature environment. 10 Especially, the skin material can be used as structural components of heat exchangers using CO_2 refrigerant that especially excellent high temperature strength is required.

The manufacturing apparatus for clad material according to the present invention is not limited to the manufacturing apparatus 15 1 having the structure shown in Fig. 1, but can employ various structures having the same function.

The cooling roller in the manufacturing apparatus of the present invention corresponds to the cooling roller 2a and 2b of the manufacturing apparatus 1 of the illustrated embodiment. 20 Similarly, the molten-metal supplying portion corresponds to a molten-metal preparation portion which is located outside the drawing and arranged in front of the nozzle 3. The skin material feeding portion corresponds to the aforementioned holding roll 4a (4b) and the tension roll for adjusting the tension of the skin 25 material coil located outside the drawing or the tension of the skin member, etc.

Examples

It should be understood that the following examples do not limit the scope of the invention.

5 Using the apparatus 1 for manufacturing the clad material as shown in Fig. 1 and explained above, the three-layered clad material 12 of the present invention was manufactured.

 In each following Examples 1 to 3, as the alloy constituting a core material and a skin material, the aluminum alloys having
10 the chemical composition shown in Table 1 were used.

Table 1

Alloy No.	Chemical composition (mass%), the balance being Al and inevitable impurities											
	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Zr	V	Sc
(a)	0.10	0.25	0.02	0.01	0.01	<0.01	<0.01	0.02	0.01	<0.01	<0.01	<0.01
(b)	0.08	0.20	0.02	0.01	0.01	<0.01	<0.01	0.04	0.01	0.18	<0.01	<0.01
(c)	0.25	0.50	0.12	0.02	0.01	0.01	<0.01	0.04	0.05	<0.01	<0.01	<0.01
(d)	0.25	0.40	0.15	1.05	0.01	0.01	<0.01	0.05	0.02	<0.01	<0.01	<0.01
(e)	0.25	0.40	0.15	0.95	0.01	0.20	<0.01	0.05	0.05	0.18	<0.01	<0.01
(f)	7.85	0.65	0.07	0.04	0.02	0.01	<0.01	0.10	0.02	<0.01	<0.01	<0.01
(g)	0.30	0.60	0.14	0.05	1.52	0.04	<0.01	0.15	0.05	<0.01	<0.01	<0.01
(h)	0.20	0.35	0.07	0.07	2.25	0.24	<0.01	0.08	0.05	<0.01	<0.01	<0.01
(i)	0.48	0.33	0.05	0.04	0.55	0.03	<0.01	0.04	0.03	<0.01	<0.01	<0.01
(j)	0.20	0.42	0.05	0.04	0.03	<0.01	<0.01	1.15	0.10	<0.01	<0.01	<0.01
(k)	0.30	0.45	1.65	0.25	2.55	0.22	<0.01	5.55	0.10	0.18	<0.01	<0.01
(l)	0.25	0.40	0.18	1.05	0.01	0.01	<0.01	0.05	0.02	<0.01	<0.01	<0.01
(m)	4.55	0.55	0.06	0.04	0.02	0.01	<0.01	2.20	0.02	<0.01	<0.01	<0.01
(n)	8.85	0.65	0.07	0.04	0.02	0.01	<0.01	2.20	0.02	<0.01	<0.01	<0.01
(o)	15.80	0.64	0.07	0.04	0.02	0.01	<0.01	2.20	0.02	<0.01	<0.01	<0.01
(p)	0.20	0.42	0.05	0.04	0.03	<0.01	<0.01	0.15	0.10	<0.01	<0.01	<0.01
(q)	0.20	0.42	0.05	0.04	0.03	<0.01	<0.01	2.55	0.10	<0.01	<0.01	<0.01
(r)	0.20	0.42	0.05	0.04	0.03	<0.01	<0.01	10.50	0.10	<0.01	<0.01	<0.01
(s)	0.30	0.38	0.05	1.05	0.01	0.01	<0.01	1.50	0.02	<0.01	<0.01	<0.01
(t)	8.50	0.45	0.10	0.04	0.02	0.01	<0.01	1.50	0.04	<0.01	<0.01	<0.01
(u)	0.60	0.40	0.35	0.05	0.10	0.05	<0.01	0.85	0.05	<0.01	<0.01	<0.01
(v)	0.80	0.50	0.35	1.55	0.10	0.15	<0.01	0.80	0.18	<0.01	<0.01	<0.01
(w)	1.10	0.60	0.35	1.55	0.10	0.25	<0.01	0.80	0.18	<0.01	<0.01	<0.01
(x)	1.10	0.65	0.45	1.55	0.15	0.25	<0.01	0.80	0.18	0.25	<0.01	<0.01
(y)	1.10	0.65	0.45	1.55	0.15	0.25	<0.01	0.80	0.18	<0.01	0.20	<0.01
(z)	1.10	0.65	0.45	1.55	0.15	0.25	<0.01	0.80	0.18	<0.01	<0.01	0.25

[Example 1]

This Example 1 is an example about the stability of the skin material and the structure of the core material by the heat cladding conditions.

5 As a skin material 10a and 10b, an ingot made of the alloys Nos. (a), (c), (f) and (j) shown in Table 1 and manufactured by a semi-continuous casting method was subjected to hot rolling, intermediate annealing at 370 °C x 4 h, then cold rolling and intermediate annealing if needed, to thereby obtain a material having
10 a thickness t1 of 0.20 mm.

 As for the inventive examples Nos. 1 to 10 and the comparative examples Nos. 11 to 19, and 21 shown in Table 2, using the aforementioned clad material manufacturing apparatus 1, a three-layered heat rolled clad material 12 with the skin materials
15 10a and 10b clad on both surfaces of the core material 11 was manufactured.

 In detail, in the state in which the skin materials 10a and 10b whose reference sign is shown in Table 2 were set and rotated with the skin material 10a and 10b contacting the peripheral surface
20 of the cooling rollers 2a and 2b, the molten metal M having the core material compositions (b), (d), (e), (g), (h), (i) and (k) shown in Table 2 was poured from the above. At this time, the target thickness of the core material 11 after the heat roll cladding was set to 4.0 mm. Moreover, the contact distance L1 from the contact
25 starting point P1 where the aforementioned skin material 10a (10b) begins to come into contact with the cooling roller 2a (2b) to the

meeting point P2 where the skin material begins to come into contact with the molten metal M was set to 100 or 150 times of the thickness t1 of skin material 10a (10b) in the Inventive examples Nos. 1 to 10, and set to 50 or 80 times of the thickness t1 of the skin material 10a (10b) in the comparative examples Nos. 11 to 19, and 21. Although the pouring temperature of the molten metal M was different depending on the composition of the core material 11, in order to prevent dissolution of the skin material 10a (10b), it was set such that it became higher than the solidification start temperature by about 5 to about 30 °C. Moreover, the peripheral speed of the cooling roller 2a (2b) was set to 30 m/min.

About the manufactured three-layered clad materials 12, the skin material breakage and the skin material melting ratio were evaluated by the following standard, and the average dendrite secondary arm spacing (DAS) of the core material was also measured. These results are shown in Table 2.

(Skin material breakage)

In the case where there was a breakage during the manufacturing the three-layered clad material 12 of 100m length, it was noted as "yes," and in the case where there was no breakage, it was noted as "no." A skin material noted as "no" skin material breakage was evaluated as a good article.

(Skin material melting rate)

The skin material melting rate was expressed by percentage

obtained by performing five-point sampling from the organization observation of the cross-section of the hot rolled clad plate and averaging the five maximum values of the molten portions of the skin material and then dividing the average value by the original thickness of the skin material. Here, it was calculated under the assumption that there was no area reduction of the skin material due to rolling. In the case where the skin material melting rate was 5% or less, it was evaluated as a good article.

10 (Average DAS)

An arbitrary length L parallel to the dendrite principal axis was obtained as an average value by performing five point measurements at the value by divided by the number N of the secondary arm which exists therein. In the case where the average DAS was 10 μm less was estimated as a good article.

Subsequently, after cold rolling each hot rolled clad material into a thickness of 110 μm , heat treating of 600 $^{\circ}\text{C}$ x 10 min. was performed. This heat treating was heat-treatment supposing brazing. As for the inventive example No. 6 and the comparative example No. 16, they were subjected to heat treating of 170 $^{\circ}\text{C}$ x 5 h. As for the inventive example No. 9 and the comparative example No. 19, they were subjected to heat treating of 120 $^{\circ}\text{C}$ x 3h. The heat treatment was a post-aging treatment intended to improve the strength of the core material.

25 About the clad material after the aforementioned cold rolling

and heat treating, the tensile strength at ordinary temperature and the tensile strength after holding at 180 °C x 10h were measured. These results are shown in Table 2.

On the other hand, as for the comparative example No. 20 shown in Table 2, the core material had the composition (b) and the skin material had the composition (f) shown in Table 1. Initially, the ingot manufactured by the semi-continuous casting method was subjected to pre-heating and hot rolling after cutting the surface portion. The skin material having a thickness of 20 mm and the core material having a thickness of 400 mm after the surface cutting of the ingot surface were hot rolled to thereby obtain a hot rolled plate having a total thickness of 5 mm. Furthermore, the hot rolled plate with a thickness of 5 mm was cold-rolled into a thickness of 110 µm, and then subjected to heat treatment of 600 °C x 10 min.

The skin material breakage, skin material melting rate, and core material average DAS of the hot rolled plate was evaluated. The skin material breakage and the skin material melting rate were evaluated by the same method as in the aforementioned invention. The core material average DAS was the value of the central portion of the ingot (400mm thickness) having the composition (b) to be used as a core material. Moreover, as to the cold rolled plate with a thickness of 110mm, the tensile strength after 10 hours holding at ordinary temperature and 180 °C was measured. These results are shown in Table 2.

Table 2

Clad material No.	Hot rolled clad material				Cold rolling	Heat treatment		Quality of heat rolled clad material			Tensile strength		
	Material composition (three layered clad)					Total thickness of after the cold rolling (μm)	Heating conditions	Late aging conditions	Skin breakage	Skin melting rate (%)	Core average DAS (μm)	Normal temp. strength (MPa)	180°C strength (MPa)
	Skin/core/ski	Thickness of the skin t1 (mm)	Thickness of the core (mm)	L1/t1									
Invention	1	(a)(b)(a)	0.20	4.0	100	110	600°Cx10 min	—	No	<1	5.2	110	65
	2	(c)(b)(c)	0.20	4.0	100	110		—	No	<1	4.8	115	67
	3	(f)(d)(f)	0.20	4.0	100	110		—	No	3	3.8	135	78
	4	(f)(e)(f)	0.20	4.0	100	110		—	No	3	4.2	145	82
	5	(j)(e)(j)	0.20	4.0	100	110		—	No	<1	4.4	143	80
	6	(f)(g)(f)	0.20	4.0	100	110		170°Cx5h	No	2	6.0	125	75
	7	(f)(h)(f)	0.20	4.0	100	110		—	No	3	6.5	180	110
	8	(f)(i)(f)	0.20	4.0	100	110		—	No	3	6.2	210	170
	9	(f)(k)(f)	0.20	4.0	100	110		120°Cx3h	No	3	5.5	480	210
	10	(a)(b)(a)	1.20	4.0	150	110		—	No	<1	4.9	111	66
Comp.	11	(a)(b)(a)	0.20	4.0	50	110	600°Cx10 min	—	Yes	6	12.4	98	59
	12	(c)(b)(c)	0.20	4.0	50	110		—	Yes	6	13.2	102	60
	13	(f)(d)(f)	0.20	4.0	50	110		—	Yes	20	11.3	115	70
	14	(f)(e)(f)	0.20	4.0	50	110		—	Yes	22	11.5	120	72
	15	(j)(e)(j)	0.20	4.0	50	110		—	Yes	7	12.0	118	69
	16	(f)(g)(f)	0.20	4.0	50	110		170°Cx5h	Yes	14	16.3	120	72
	17	(f)(h)(f)	0.20	4.0	50	110		—	Yes	12	14.9	175	104
	18	(f)(i)(f)	0.20	4.0	50	110		—	Yes	13	15.5	180	111
	19	(f)(k)(f)	0.20	4.0	50	110		120°Cx3h	No	7	13.8	410	195
	20	(f)(b)(f)	20/400/200mm, hot roll clad into total thickness of 5 mm			110		—	Yes	6	25.2	75	48
	21	(a)(b)(c)	0.20	4.0	80	110		—	Yes	6	11.5	110	60

From the result shown in Table 2, it was confirmed that in each invention manufactured by the method of the present invention the skin material was not broken, there was very few melting of the skin material, and it was stably manufactured. Moreover, in 5 the manufactured clad material, it was confirmed that the average DAS was 10 μm or less, and it was excellent in high temperature strength.

[Example 2]

10 This Example 2 is an example about brazing performance and corrosion resistance by the skin material components and the skin material.

As a skin material 10a and 10b, an ingot manufactured from the alloys Nos. (m) to (r) in Table 1 by a semi-continuous casting 15 method was subjected to hot rolling, intermediate annealing at 370 °C x 4 h, then cold rolling and intermediate annealing if needed, to thereby obtain a material having a thickness t1 of 0.35 mm.

About the inventive examples Nos. 22 to 29 shown in Table 3, using the alloy having the composition shown in Table 1 as molten 20 metal M to be used as a core material, a three-layered clad material 12 in which skin materials 10a and 10b were pressure-bonded to the both surfaces of the core material 11 using the aforementioned apparatus 1 for manufacturing a clad material according to the example 1 was manufactured. In manufacturing, the target thickness of the 25 core material 11 after the hot roll cladding was set to 5.0 mm. The contact distance L1 from the contact starting point P1 to the

cooling roller 2a (2b) of the aforementioned skin material 10a (10b) to the meeting point P2 where the skin material comes into contact with the molten metal M was set to 200 times of the thickness t1 of skin material 10a (10b). The remaining conditions were set to the same as in Example 1.

Subsequently, each heat rolled clad material 12 was cold-rolled into a thickness of 110 μm , and then subjected to a heat treatment of 600 $^{\circ}\text{C}$ x 10 min.

About the clad material after the cold rolling and heat treatment, the tensile strength at ordinary temperature, the tensile strength after 180 $^{\circ}\text{C}$ x 10 h holding, breakage of the skin material, melting rate of the skin material, the quality of hot rolled clad material with an average DAS were measured or evaluated. These results are shown in Table 3.

Moreover, as to the cold-rolled three-layered clad material 12, the brazing performance and the corrosion resistance were evaluated by the following method.

(Brazing performance)

As to the inventive examples No. 22, 24, 25, 28 and 29 using (m), (n), and (o) as a skin material, using the aluminum alloy having the composition (s) shown in Table 1, it was rolled into a sheet having a thickness of 80 μm and processed into the fin 20 shown in Fig. 2. Moreover, as to the inventive examples Nos. 23, 26 and 27 using (p), (q) and (r) as a skin material, a three-layered clad material (5 μm / 70 μm / 5 μm , the total thickness of 80 μm) having

compositions (n), (s) and (n) shown in Table 1 was manufactured, and then processed into the fin 20 shown in Fig. 2 in the same manner as mentioned above. Each of the aforementioned fins (20) had a fin thickness (Ft): 80 μ m, a fin pitch (Fp): 2.0 mm and a fin height (Fh): 8 mm.

And as shown in Fig. 2, fins 20 and 20 were attached to both surfaces of the aforementioned three-layered clad material 12, and flux was applied thereto. Then, they were subjected to a brazing test by heating at 600 °C x 10 min.

About these brazed articles, the junction rate and erosion were investigated. In the evaluation of the junction rate, the length that the fin 20 was detached was measured by cutting the fin, and calculated by the following formula: $[1 - (\text{fin detached length}) / (\text{the entire fin joining portion})] \times 100$. In the case where the calculated result was 80% or more, it was shown as "o." In the case where the calculated result was less than 80%, it was shown as "x." In the erosion valuation, in cases where the erosion depth was less than 20 μ m, it was shown as "o," and in cases where the erosion depth exceeded 20 μ m, it was shown as "x."

(Corrosion resistance)

A brazed article constituted by the three-layered clad material 12 and fin 20 subjected to the brazing test was subjected to SWAAT Test (Synthetic sea Water Acetic Acid salt spray Test) defined in ASTM-G85-A3 to investigate generation of apertures and fin detaching performances. The test conditions were as follows. Corrosion test

liquid adjusted so as to be pH3 by adding acetic acid to artificial seawater according to ASTM D1141 was used. A cycle of spraying the corrosion test liquid against the article for 0.5 hours and holding the article for 1.5 hours under the wet condition was repeated for
5 960 hours.

In evaluating the generation of pitting corrosion, in cases where no through-hole was formed in the clad material 12 after 960 hours, it was noted as "○," and in cases where through-holes were formed, it was noted as "×." In evaluating the fin detachment, the
10 sample fin subjected to the corrosion test was cut, and the similar evaluation as in the joint rate was performed. As a result, in cases where the rate was 80% or more, it was noted as "○," and in cases where the rate was less than 80%, it was noted "×."

Table 3

Clad material No.	Hot rolled clad material				Cold rolling	Heat treatment	Tensile strength		Brazing performance		Corrosion resistance		Quality of hot rolled clad material				
	Material composition (three layered clad)						Total thickness of after the cold rolling (μ m)	Heating conditions	Normal temp. strength (MPa)	180°C strength (MPa)	Joining rate	Erosion	Generation of apertures	Fin detachment	Breakage of skin material	Melting rate of skin material (%)	Average DAS of skin material (μ m)
	Skin/core/skin	Thickness of the skin tl (mm)	Targeted thickness of the core (mm)	L1/t1													
22	(n)(l)(n)	0.35	5.0	200	110	600°Cx10 min	140	80	○	○	○	○	○	No	<1	4.0	
23	(q)(l)(q)	0.35	5.0	200	110		135	78	○	○	○	○	○	○	No	<1	4.4
24	(m)(l)(m)	0.35	5.0	200	110		137	78	x	○	○	x	○	○	No	<1	4.2
25	(o)(l)(o)	0.35	5.0	200	110		142	83	○	○	x	○	○	○	No	<1	3.8
26	(p)(l)(p)	0.35	5.0	200	110		130	78	○	○	○	○	x	○	No	<1	4.6
27	(r)(l)(r)	0.35	5.0	200	110		135	82	○	○	○	○	○	x	No	<1	4.8
28	(n)(l)(n)	0.01	5.0	200	110		140	80	○	○	○	○	○	○	No	<1	3.6
29	(n)(l)(n)	0.50	5.0	200	110		130	77	○	○	○	○	○	○	No	<1	5.0
Invention																	

From the result shown in Table 3, it was confirmed that by using the aluminum alloy of the predetermined composition as a skin material outstanding brazing performance and corrosion resistance could be obtained. It was further confirmed that breakage of the skin material, melting rate of the skin material and average DAS of the skin material in each clad material were excellent.

[Example 3]

This example 3 is an example about an evaluation of the strength by the core material composition.

As a skin material 10a and 10b, an ingot manufactured from the alloy No. (t) in Table 1 by a semi-continuous casting method was subjected to hot rolling, intermediate annealing at 370 °C x 4 h, then cold rolling and intermediate annealing if needed, to thereby obtain a material having a thickness t1 of 0.25 mm.

About the inventive examples Nos. 30 to 35 shown in Table 4, using the alloys having compositions (u) to (z) shown in Table 1 as molten metal M to be used as a core material, a three-layered clad material 12 in which skin materials 10a and 10b were pressure-bonded to the both surfaces of the core material 11 using the aforementioned apparatus 1 for manufacturing a clad material according to the example 1 was manufactured. In manufacturing, the target thickness of the core material 11 after the hot roll cladding was set to 5.0 mm. The contact distance L1 from the contact starting point P1 to the cooling roller 2a (2b) of the aforementioned skin material 10a (10b) to the meeting point P2 where the skin material

comes into contact with the molten metal M was set to 200 times of the thickness t_1 of skin material 10a (10b). The remaining conditions were set to the same as in Example 1.

Subsequently, each heat rolled clad material 12 was cold-rolled into a thickness of 110 μm , and then subjected to a heat treatment of 600 °C x 10 min.

About the clad material after the cold rolling and heat treatment, the tensile strength at ordinary temperature and the tensile strength after 180 °C x 10 h holding, the quality of the hot rolled clad material, the brazing performance, and the corrosion resistance were measured. These results are shown in Table 4.

Table 4

Clad material No.	Hot rolled clad material				Cold rolling	Heat treatment	Tensile strength		Brazing performance		Corrosion resistance		Quality of hot rolled clad material			
	Material composition (three layered clad)			Total thickness of after the cold rolling (μ m)			Normal temp. strength (MPa)	180°C strength (MPa)	Joining rate	Erosion	Generation of apertures	Fin detachment	Breakage of skin material	Melting rate of skin material (%)	Average DAS of skin material (μ m)	
	Skin/core/skin	Thickness of the skin t1 (mm)	Targeted thickness of the core (mm)													
Invention	30	(t)(v)(t)	0.25	5.0	200	110	600°Cx10 min.	87	53	○	○	○	No	2	3.8	
	31	(t)(w)(t)	0.25	5.0	200	110		92	58	○	○	○	○	No	2	4.0
	32	(t)(x)(t)	0.25	5.0	200	110		143	86	○	○	○	○	No	3	4.2
	33	(t)(y)(t)	0.25	5.0	200	110		134	81	○	○	○	○	No	3	4.8
	34	(t)(z)(t)	0.25	5.0	200	110		152	92	○	○	○	○	No	3	4.4
	35	(t)(u)(t)	0.25	5.0	200	110		65	38	○	○	○	○	No	2	3.8

From the result shown in Table 4, it was confirmed that by using the aluminum alloy of the predetermined composition as a core material outstanding high temperature strength could be obtained. Furthermore, it was confirmed that the breakage of the skin material, the melting rate of the skin material, the average DAS of the core material, the brazing performance and the corrosion resistance were excellent.

(Workability)

About each of the clad materials shown in Table 5 among the clad materials shown in Tables 2, 3 and 4, the workability was evaluated based on the formability when the clad material was formed by roll forming into a fin (20) shape as follows. In cases where it was formed into a preferable shape, it was noted as "◎," in cases where it was formed into a fin shape although there were variations in fin shape dimension, it was noted as "○," and in cases where it was impossible to form into a fin shape due to an occurrence of breakage, it was noted as "×."

20

25

Table 5

Clad material No.		Workability
Inventive article	1	◎
	4	○
Comparative article	11	×
	12	×
Inventive article	22	○
	30	◎
	31	◎
	32	○
	33	○
	34	○
	35	◎

From the results shown in Table 5, it was confirmed that the clad materials according to the present invention was superior to the comparative articles in workability. Furthermore, it was also confirmed that the inventive articles not exhibited excellent tensile strength or brazing performance in Tables 2 to 4 were superior to comparative articles in workability.

In the above-mentioned Examples 1 to 3, the thickness t1 of the skin material 10a (10b) was not changed while the skin materials 10a and 10b were being clad onto the core material 11. However, the present invention is not limited to it. The present invention also includes the case in which the thickness of the skin material decreases due to the cladding by receiving a slight rolling pressure together with the core material when the skin materials passes through the cooling rollers 2a and 2b.

Industrial Applicability

The clad material manufactured by the present invention includes a core material and skin materials clad on the both surfaces of the core material, wherein the composition of the skin material is different from that of the core material. The clad material can be used for manufacturing metallic material to which the aforementioned characteristics were given by cladding brazing material or corrosion resistance material as skin material.

10

While the present invention may be embodied in many different forms, a number of illustrative embodiments are described herein with the understanding that the present disclosure is to be considered as providing examples of the principles of the invention and such examples are not intended to limit the invention to preferred embodiments described herein and/or illustrated herein.

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While illustrative embodiments of the invention have been described herein, the present invention is not limited to the various preferred embodiments described herein, but includes any and all embodiments having equivalent elements, modifications, omissions, combinations (e.g., of aspects across various embodiments), adaptations and/or alterations as would be appreciated by those in the art based on the present disclosure. The limitations in the claims are to be interpreted broadly based on the language employed in the claims and not limited to examples described in the present specification or during the prosecution of the application, which

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examples are to be construed as non-exclusive. For example, in the present disclosure, the term "preferably" is non-exclusive and means "preferably, but not limited to." In this disclosure and during the prosecution of this application, means-plus-function or

5 step-plus-function limitations will only be employed where for a specific claim limitation all of the following conditions are present in that limitation: a) "means for" or "step for" is expressly recited; b) a corresponding function is expressly recited; and c) structure, material or acts that support that structure are not recited. In

10 this disclosure and during the prosecution of this application, the terminology "present invention" or "invention" may be used as a reference to one or more aspect within the present disclosure. The language present invention or invention should not be improperly interpreted as an identification of criticality, should not be

15 improperly interpreted as applying across all aspects or embodiments (i.e., it should be understood that the present invention has a number of aspects and embodiments), and should not be improperly interpreted as limiting the scope of the application or claims. In this disclosure and during the prosecution of this application,

20 the terminology "embodiment" can be used to describe any aspect, feature, process or step, any combination thereof, and/or any portion thereof, etc. In some examples, various embodiments may include overlapping features. In this disclosure and during the prosecution of this case, the following abbreviated terminology may be employed:

25 "e.g." which means "for example;" and "NB" which means "note well."